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A DIGITAL TEMPERATURE MONITOR FOR PHOTORECORDING

by

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ABSTRACT

A method of digitizing atmospheric measurements for portrayal with a time-lapse camera is described. A servomechanism rebalances a resistance bridge which has the temperature sensor as an active component. A mechanically coupled encoder determines the proper combination of relay closures which, in turn, causes the temperature to be projected by means of a light bank.

During a recent study of rime accumulation in high-elevation lodgepole pine stands, an unattended time-lapse camera provided the main record. Air and dewpoint temperatures were included in the photorecord to assist in the analysis of the riming events as they appeared in the photos. Pictures were taken at 6-minute intervals during daylight hours. Film was retrieved monthly and subsequently analyzed.

Several methods of including data in the photorecord were considered. The simplest method would require exposing a series of large dials representing the analogs of the atmospheric measurements. Although this has the advantage of simplicity, several disadvantages precluded its use here. These were low resolution at times of poor visibility or during inclement weather (snow or ice coating the dials for lengthy periods), low-temperature failure of mechanical components, difficulties of separation of sensor and dial output, and restrictive input signals.

The system used has considerable flexibility regarding sensor location and measurement portrayed on the light banks. Although this

paper describes the system's use only as a temperature monitor (eventually including air, dewpoint, and soil surface temperatures), at times maximum windspeed and cumulative windrun were also included. Under moderate coatings of ice and snow, lights remained readable; however, under infrequent extreme conditions, loss of record did occur. Readout was obviously most legible at times of low ambient light. This was an additional advantage, since at low light levels, depth of field was restricted due to large camera aperture. For this reason, light banks were positioned near the primary focal distance (40-50 feet) where depth-of-field changes would have little effect on legibility.

Air and dewpoint temperatures were measured with similar resistance thermometers. The dewpoint (or frost point) was derived from the temperature of a thermoelectrically cooled, mirrored surface. Air temperature was measured in a suitably shielded enclosure.

The main elements in the system (figs. 1, 2, and 3) are:

1. resistance bridge network,
2. servoamplifier and motor,
3. encoder,
4. relay tree, and
5. light bank.

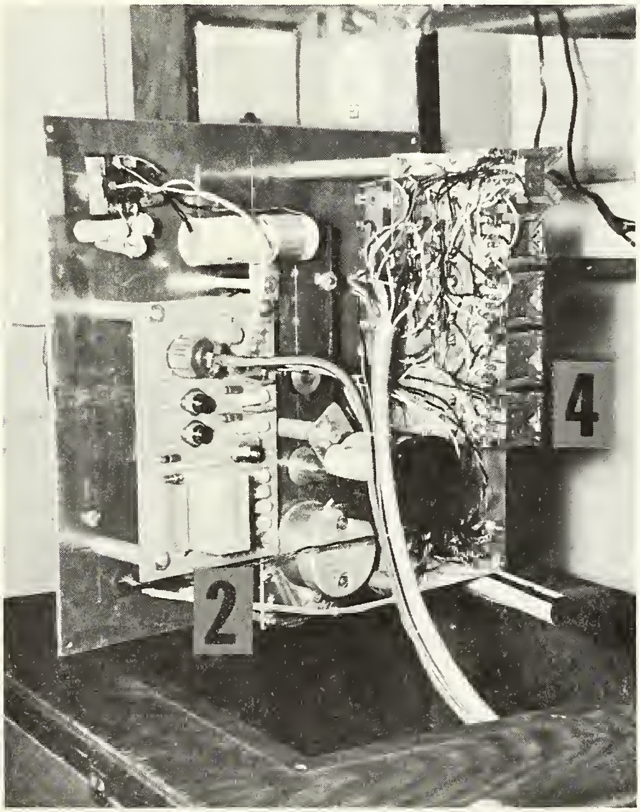


Figure 1.--Amplifier and rebalancing motor (2); relay tree (4). Numbers correspond to text description.

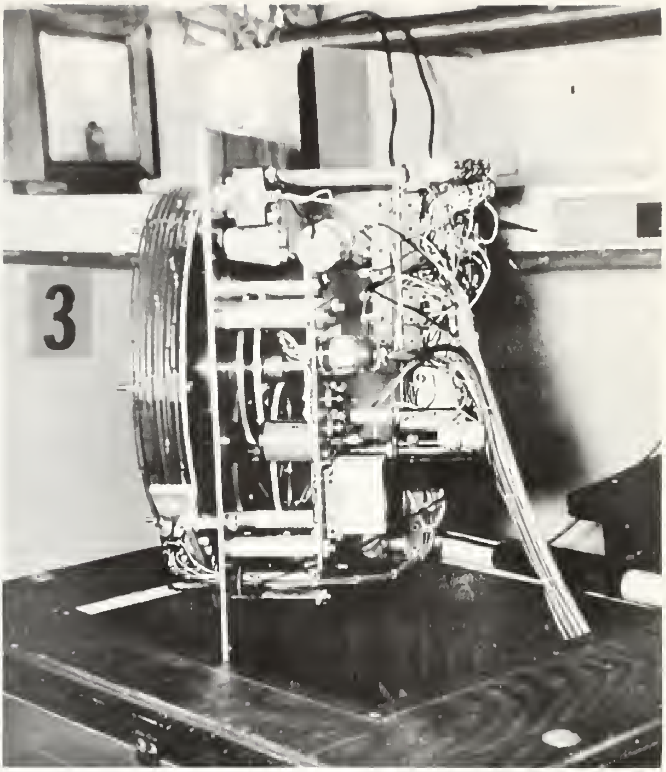


Figure 2.--Side view; note indentation on code disks (3).

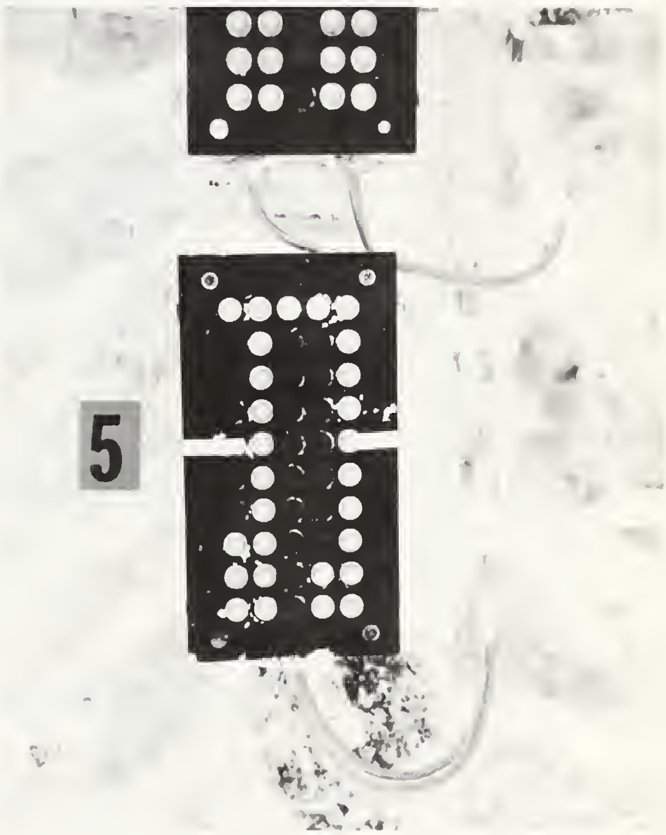
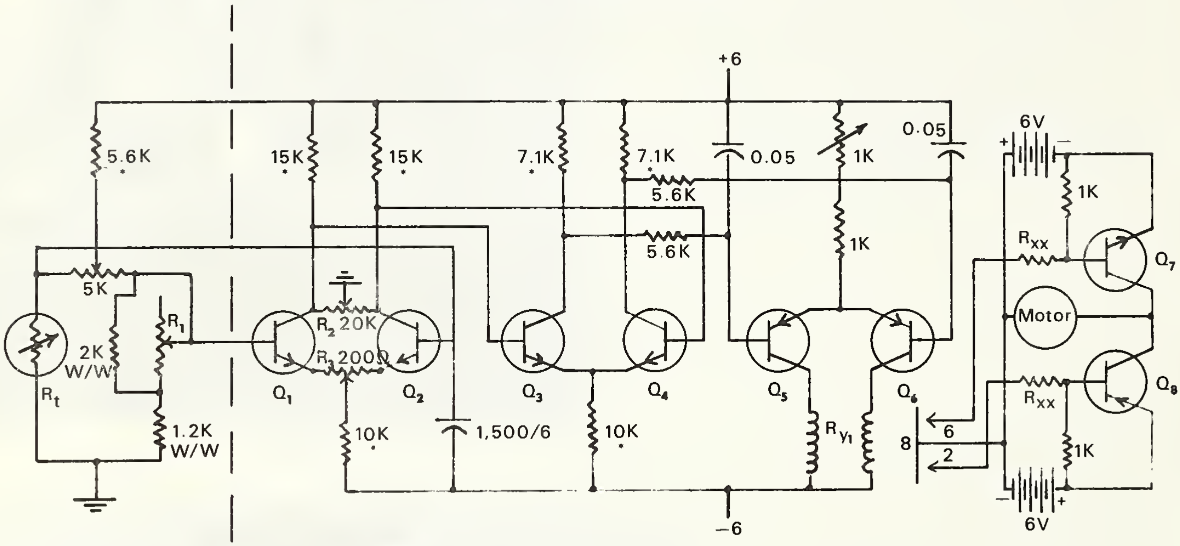


Figure 3.--Light bank; temperature indication is -11° C.

The resistance bridge (fig. 4) has two variable components--the temperature sensor and the rebalancing potentiometer. If sensor and balance potentiometer are of equal resistance, the system is stable; the servomechanism notes out-of-balance conditions and corrects them by driving the potentiometer in the proper direction to rebalance the system.

Figure 4.--Schematic drawing of servoamplifier, resistance bridge, and motor control.



Resistance bridge

Q_1-Q_4: 2N 338
Q_5,Q_6: 2N 414
Q_7 : 2N 1308
Q_8 : 2N 1309

Amplifier

R_1 : 1,000 ohms, 10 turns
R_{Y_1} : Micropositioner relay, AYLZ H 4013S
R_t : Microsensor, type TE3A-C1-2000
R_{xx}: Nominal, 3,000 ohms, chosen for adequate base drive

Motor : Haydon, No. H5309 6VDC, 10 r.p.m
Note : • = ¼ W 1 percent film
W/W = ½ W 1 percent wirewound
Otherwise ½ W 5 percent carbon

The servoamplifier[1/] [2/] has three stages of amplification driving a sensitive differential relay. If the bridge is unbalanced, relay contacts 2 and 8 or 6 and 8 close, providing base current to the motor control transistors. PNP and NPN transistors with a center-tapped supply provide the proper motor shaft rotation for rebalancing the resistance bridge. Use of low-grain differential stages reduces temperature effects on amplifier operation. Transistors Q_1 and Q_2 are mounted in an aluminum block to equalize temperature drift. These transistors were matched over the range of 0° to 20° C. by cooling the mounting block. Variable resistances R_2 and R_3 were adjusted during this cycling

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1/ Carroll, J. M. Transistor circuits and applications. 283 pp., illus. New York: McGraw-Hill Book Co., Inc. 1957.

2/ Turner, L. P. Handbook of semiconductor electronics. 664 pp., illus. New York: McGraw-Hill Book Co., Inc. 1962.

to reduce any residual transistor differences. Reduction of temperature effects over this range to an equivalent error of less than ± 0.25° C. was easily accomplished in the two instruments constructed. The dead band of the system amounts to approximately 4 ohms or ± 0.25° C. over the temperature range measured. Change of the sensor resistance of less than this amount does not initiate rebalancing. Since the encoding is done on a 1° C. basis, this resolution is quite sufficient.

The reversible d.c. motor, in addition to electrically rebalancing the system, changes the position of the encoding disks coupled to the potentiometer shaft. Each of the disks controls a level of the relay tree through a perimeter-mounted microswitch. An additional microswitch is operated as the disks rotate through 0° C. to indicate polarity.

Disks were indented with the proper switching patterns after locations had been determined through calibration with a resistance decade box. Switchpoints were chosen as midway between 1° temperature locations on the disks. Code 0 was indexed by removal of material causing the normally closed contact to be closed. Code 1 closes the normally open contact.

The code[3/] [4/] [5/] used for the disks (table 1) reduces encoding errors by restricting each degree change to a single-level change in the code. Since the temperature range is balanced fairly well around the zero point and of limited range, the code is well suited to this system. Temperature measurements cover the range of +16° to -29° C.

The relay tree (fig. 5) sets the relay contacts to form digital combinations based on coded information from the shaft encoder. Level 1 is a directly controlled microswitch and requires no corresponding relay in the relay tree. It is designated as S_1. Relays Ry_2 to Ry_6 are operated by microswitch closures and correspond to code levels 2 to 6, respectively. Interrogation of this tree from left to right drives the appropriate lights. Lights are located in a two-decade configuration (00-99) with 9 in the tens decade used for poliarity indications.

An additional control system establishes camera frame timing and interrogates the code disks and the relay tree. The shutter release

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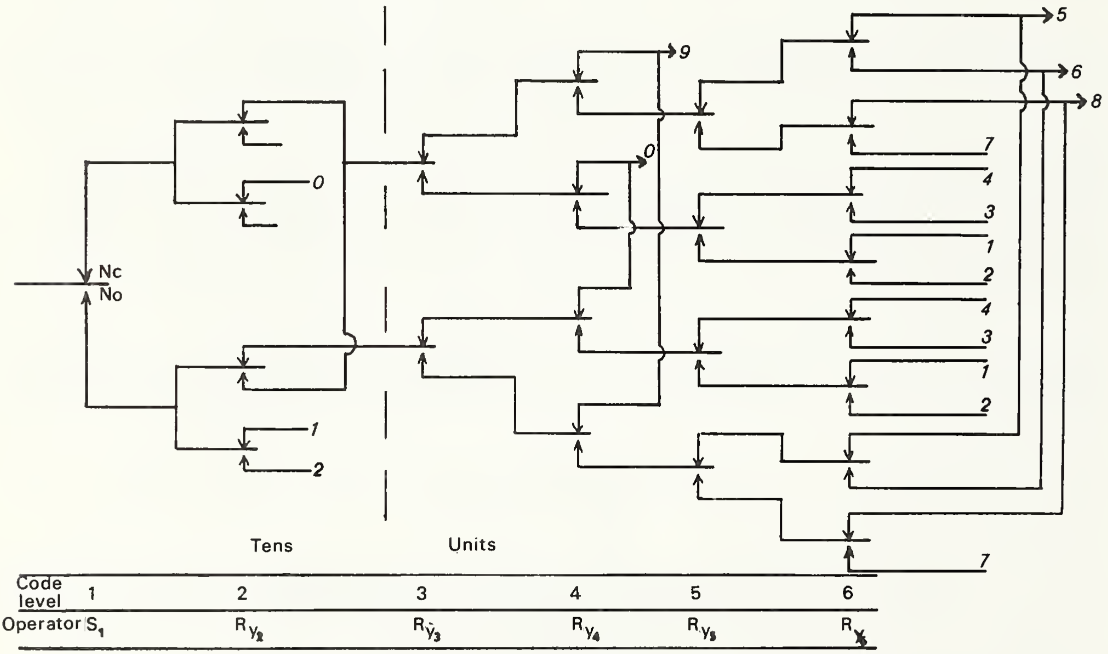
[3/] Griffin, D. P. Disk encoder design avoids ambiguities. Electronics 33(17): 62-66, illus. 1960.

[4/] Walston, J. A., and Miller, J. R. Transistor circuit design. 523 pp., illus. New York: McGraw-Hill Book Co., Inc. 1963.

[5/] Wasserman, R., and Nutting, W. Solid state digital code to code converter. Electronics 32(50): 60-63, illus. 1959.

Table 1.--*Cyclic code used in shaft position to temperature encoder*

Temperature (degrees centigrade)	Code level 1 2 3 4 5 6	Temperature (degrees centigrade)	Code level 1 2 3 4 5 6
0	0 0 1 0 1 0	15	1 0 1 1 0 0
1	0 0 1 1 1 0	16	1 0 1 1 0 1
2	0 0 1 1 1 1	17	1 0 1 1 1 1
3	0 0 1 1 0 1	18	1 0 1 1 1 0
4	0 0 1 1 0 0	19	1 0 1 0 1 0
5	0 0 0 1 0 0	20	1 1 1 0 1 0
6	0 0 0 1 0 1	21	1 1 1 1 1 0
7	0 0 0 1 1 1	22	1 1 1 1 1 1
8	0 0 0 1 1 0	23	1 1 1 1 0 1
9	0 0 0 0 1 0	24	1 1 1 1 0 0
10	1 0 0 0 1 0	25	1 1 0 1 0 0
11	1 0 0 1 1 0	26	1 1 0 1 0 1
12	1 0 0 1 1 1	27	1 1 0 1 1 1
13	1 0 0 1 0 1	28	1 1 0 1 1 0
14	1 0 0 1 0 0	29	1 1 0 0 1 0



R_{y_2}-R_{y_5}: 12V relay, Type 5 4c contacts (Universal Relay or equivalent)

R_{y_6}: 12V relay, Type 5 8c contacts (Universal Relay or equivalent)

Figure 5.--Relay tree.

is delayed to allow lights to reach full brilliance. The No. 1829 bulbs provide adequate images at a distance of 40 feet. Relays and lights operate only during camera frames to conserve battery power.

This system was designed to operate unattended and in a remote location with minimum drain on the battery supplies. Available components were used with reliability and ease of servicing preferred over compactness. The original two systems are in their second year of operation. The single operational failure thus far was due to a faulty contact in variable resistor R_1. Some economies could be effected by use of an encoding disk constructed with alternate conductive and insulated segments; however, because of possibility of contamination of these sliding contacts, the microswitches were used. A number of commercially available operational amplifiers may be substituted for the amplifier described here if desired.